



Jet Propulsion Laboratory
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A Model-based Approach to Developing the Concept of Operations for Potential Mars Sample Return

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Agenda

- Context
- Why Focus on the Concept of Operations?
- Approach
 - Overview
 - Modeling Patterns
- Results to Date & Insights
- Summary & Conclusions

A Potential Multi-Agency Mars Sample Return

- Proposed series of mission concepts to collect rock and dust samples on Mars and return them to Earth
- A letter of intent was signed by [NASA and ESA](#) that may provide basis for joint Mars Sample Return in the late 2020s
- One possible concept:
 - Mars 2020 rover [collects samples](#) and leaves them on surface
 - Later launch brings [lander with rover and ascent rocket](#) to collect samples and bring them into Martian orbit
 - Orbiter [picks up samples](#) and returns them to Earth



Concept of Operations

- A statement of the **goals and objectives**
- A series of **operational scenarios** (or *operational concepts*) that describe envisioned processes for *initiating, developing, operating* and *retiring* the system
- A clear statement of the **organizations, participants and stakeholders** involved, as well as the **delegation of responsibilities and authority**
- **Constraints, policies and strategies** affecting the system

Primary Purposes:

- Describes system characteristics from an operational perspective
- Facilitates understanding of the system goals
- Stimulates development of requirements

* Sources: IEEE 1362-1998, NASA Systems Engineering Handbook

Why *Model* the Concept of Operations?

- Long term vision: build an integrated **system model** of technical and programmatic information **collaboratively** with ESA and other NASA centers and suppliers
- MSR MBSE effort is focused on CONOPS development to:
 - Provide an architectural **framework for initial requirement development**
 - Provide **early requirements validation** by linking requirements to functions and activities
 - Process, analyze and transform the CONOPS-related information to generate reports and documents
 - Ultimately provide for the constraints of the function and activity dictionaries used in mission planning and sequence generation

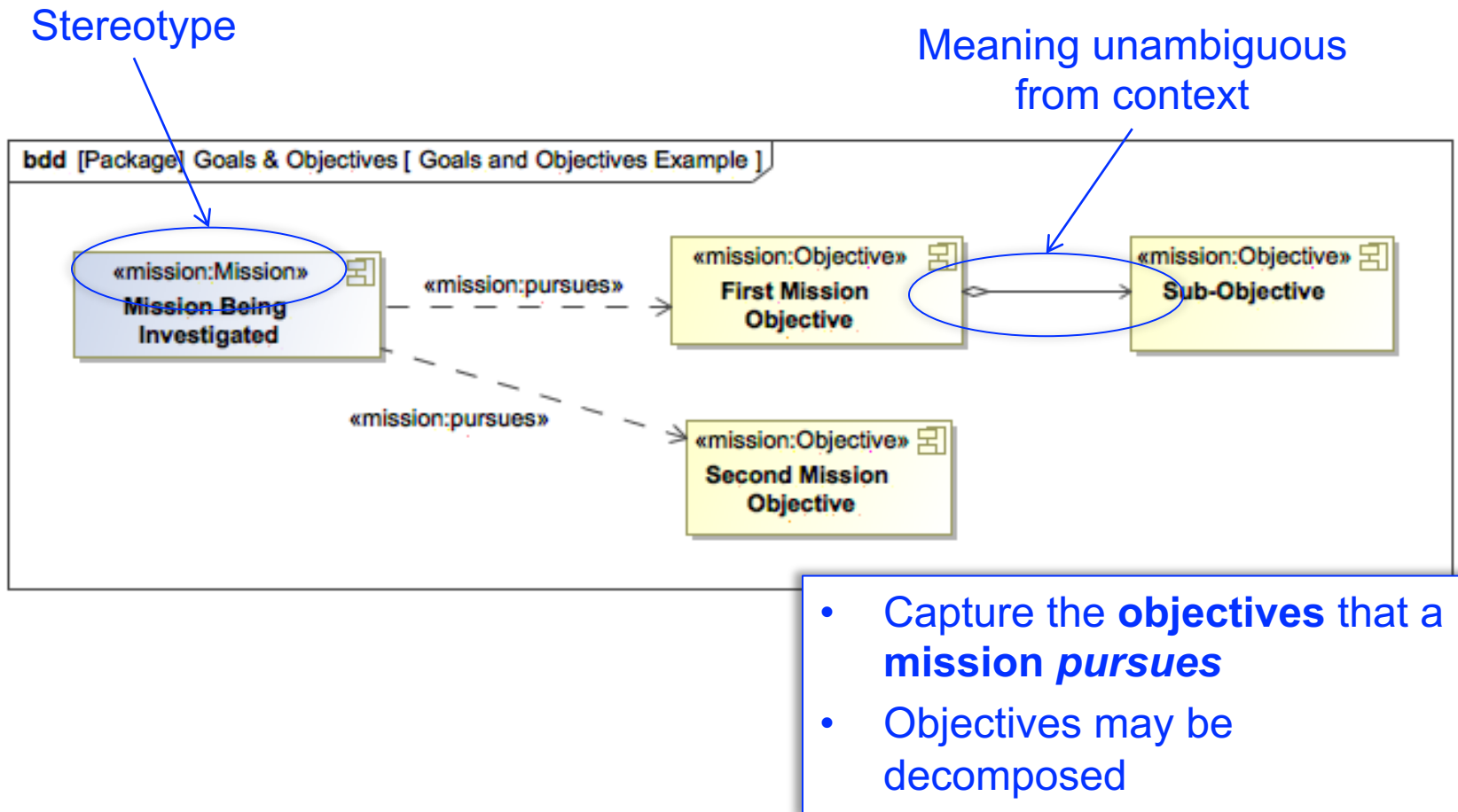
Modeling Approach Overview

- SysML / UML as a basis
- Use of an extended set of modeling constructs
 - Profile-embedding of the foundational *JPL IMCE Ontologies**
 - Extensions of provided vocabulary, as needed, and in accordance with recommended extension mechanism to conserve associated semantics
- Use of a series of specific modeling patterns for capturing the different elements of a CONOPS
- Use of the internally developed tools such as *View Editor* for document and report generation, and analysis

* Available open source at <https://bintray.com/jpl-imce/gov.nasa.jpl.imce/>

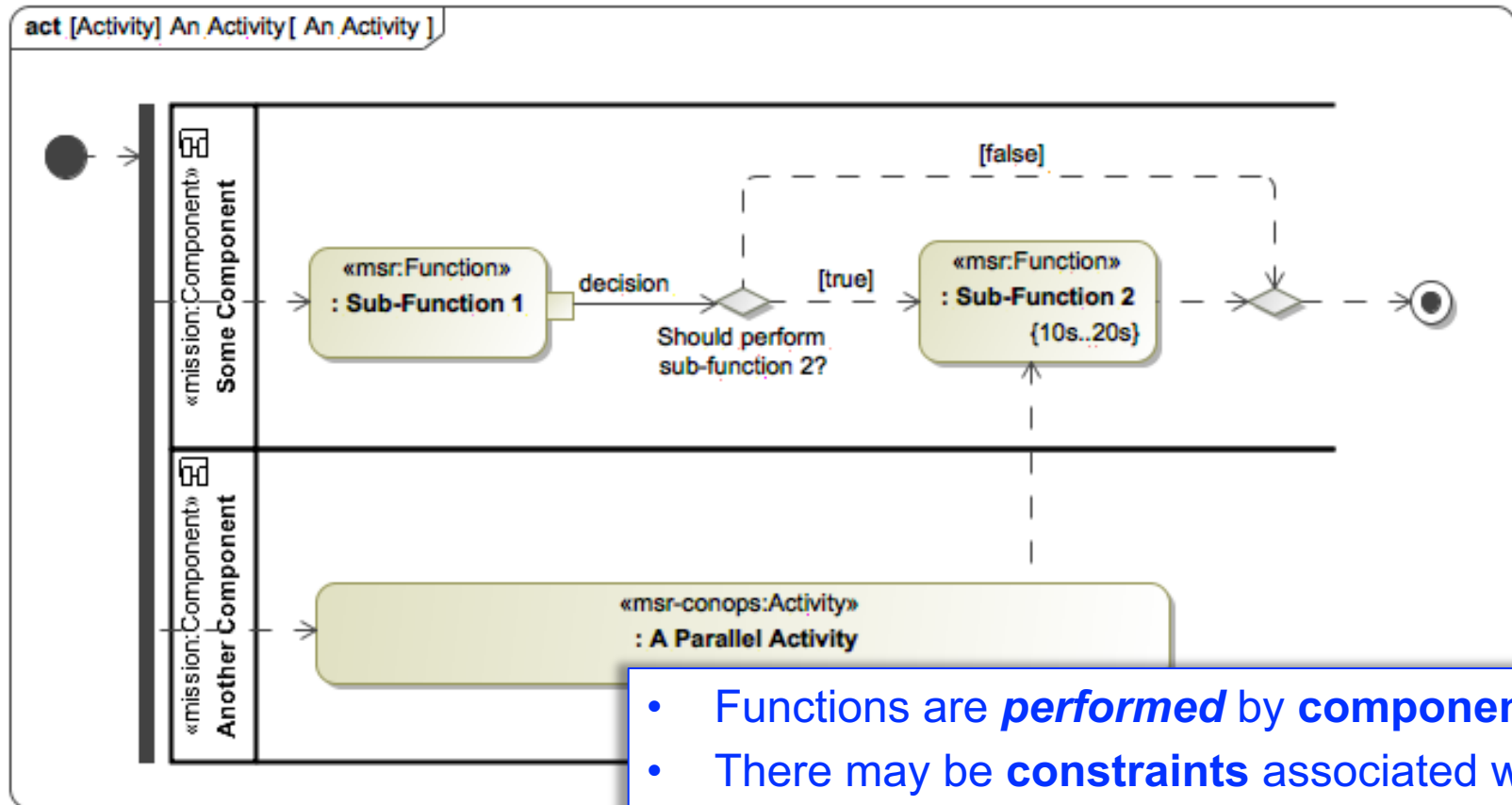
Mission Goals & Objectives

Capturing Objectives Pursued by a Mission



Operational Scenarios

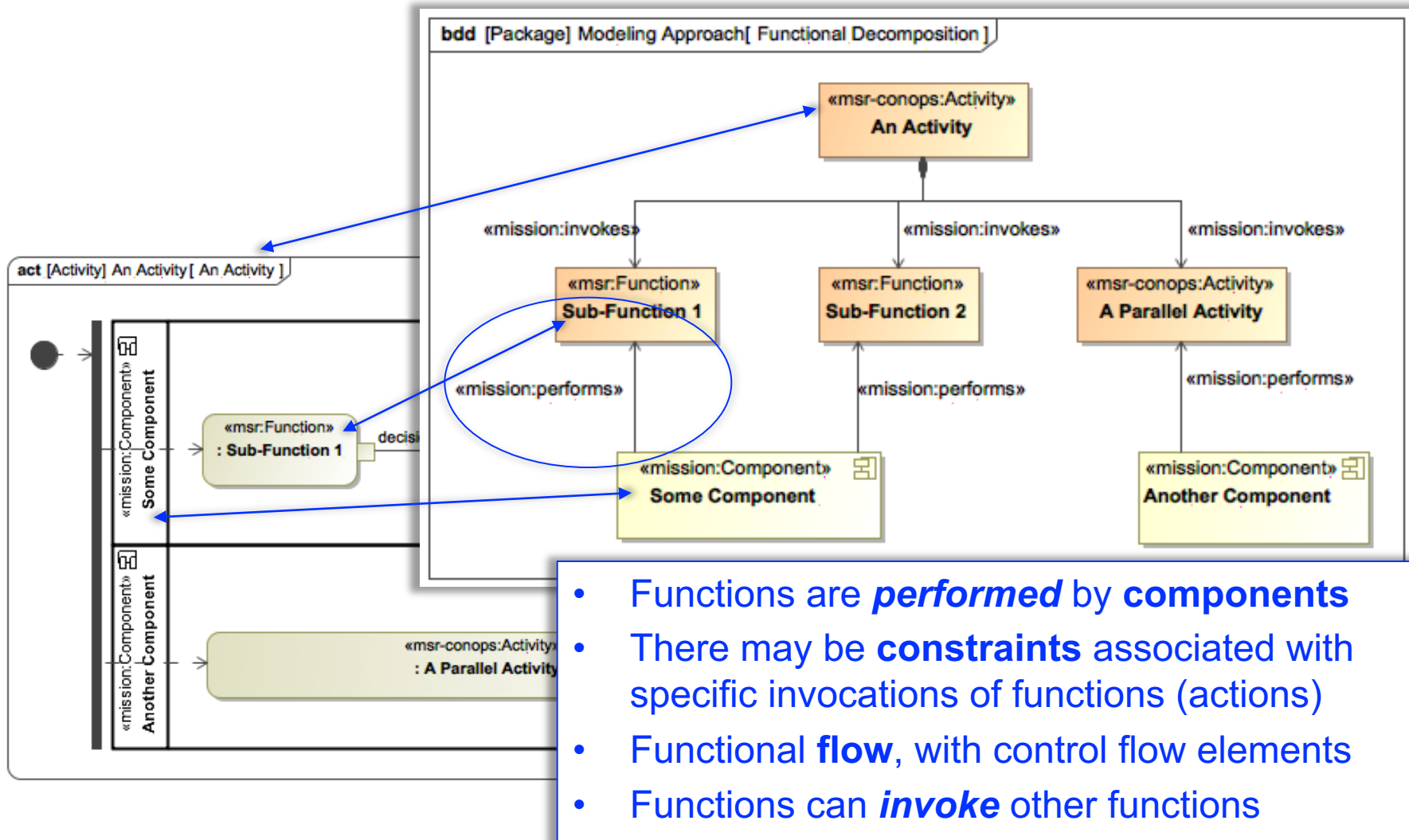
Modeling Functional Flow



- Functions are **performed** by **components**
- There may be **constraints** associated with specific invocations of functions (actions)
- Functional **flow**, with control flow elements
- Functions can **invoke** other functions

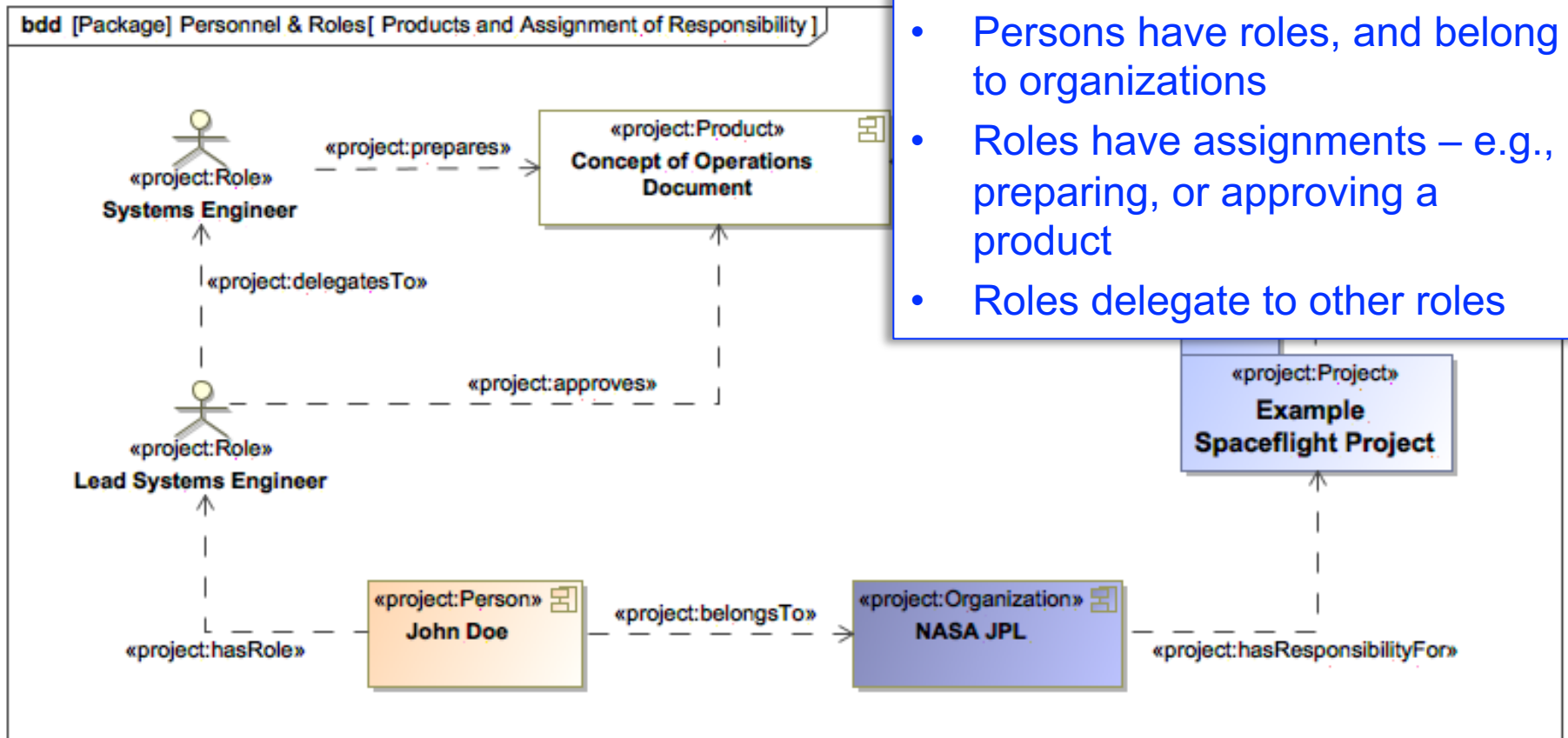
Operational Scenarios

Capturing Performing Elements



Assignment of Responsibilities & Authority Delegation

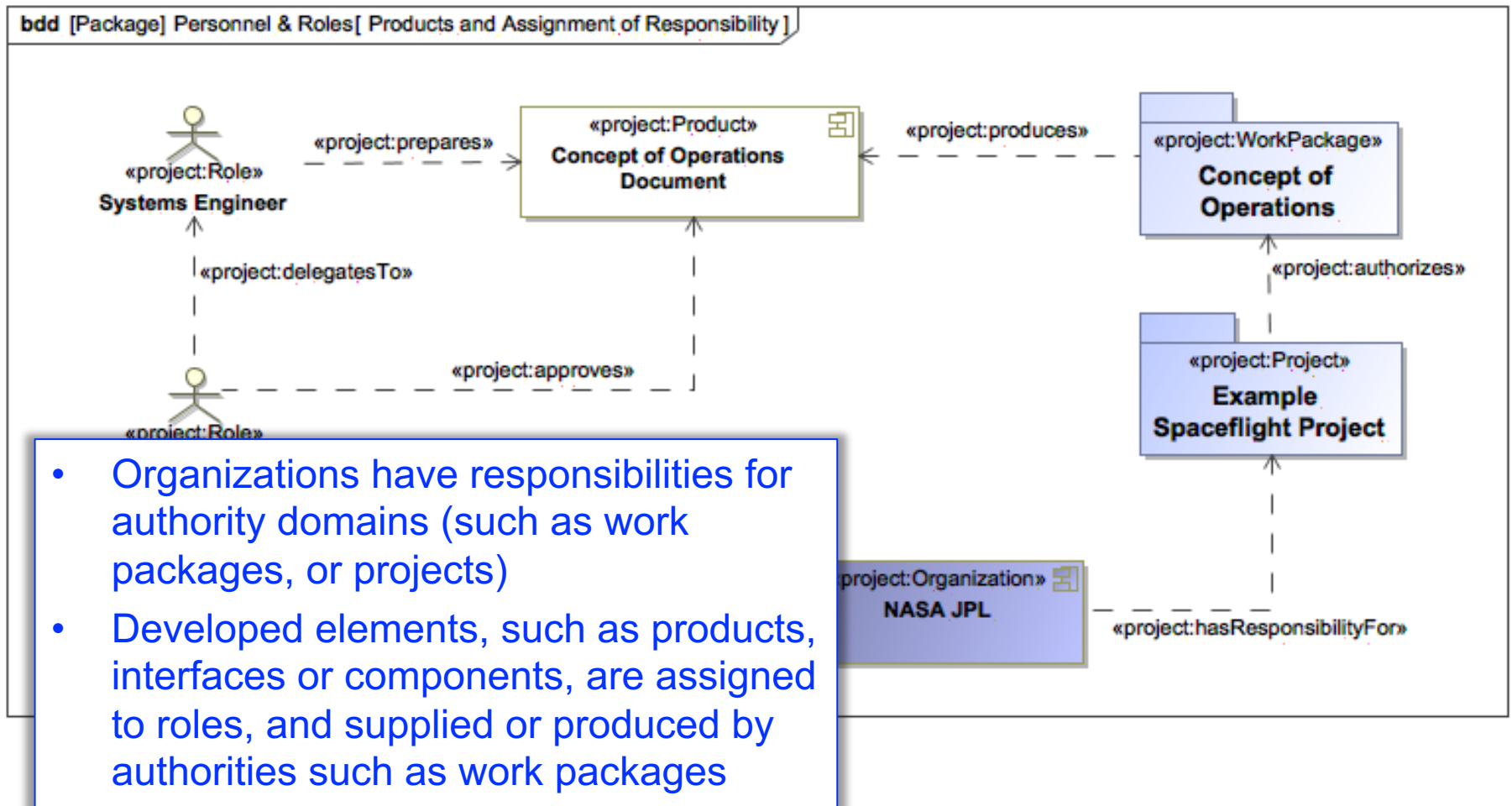
Roles & Responsibilities



- Persons have roles, and belong to organizations
- Roles have assignments – e.g., preparing, or approving a product
- Roles delegate to other roles

Assignment of Responsibilities & Authority Delegation

Authority Delegation



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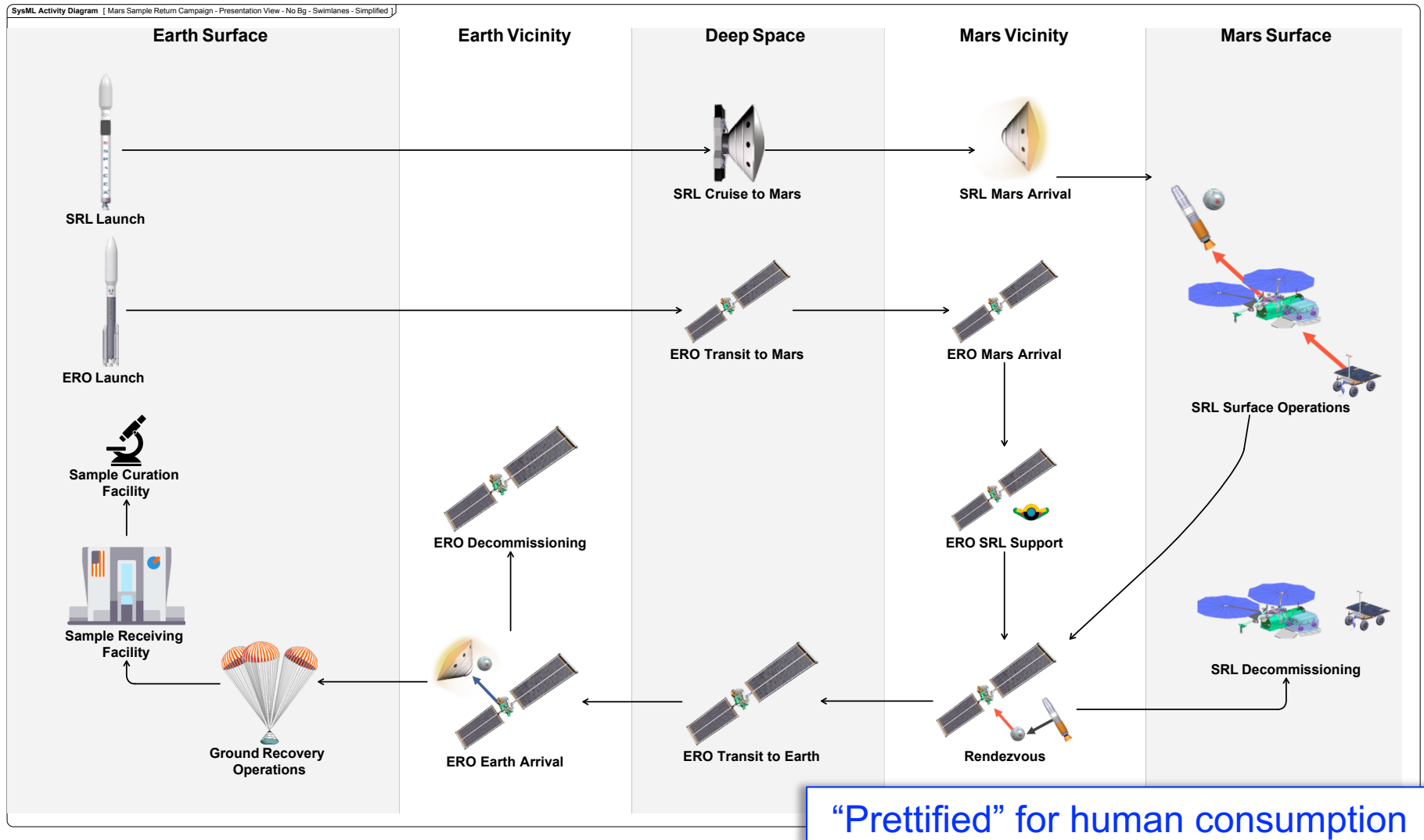
Results to Date

Current Model Content

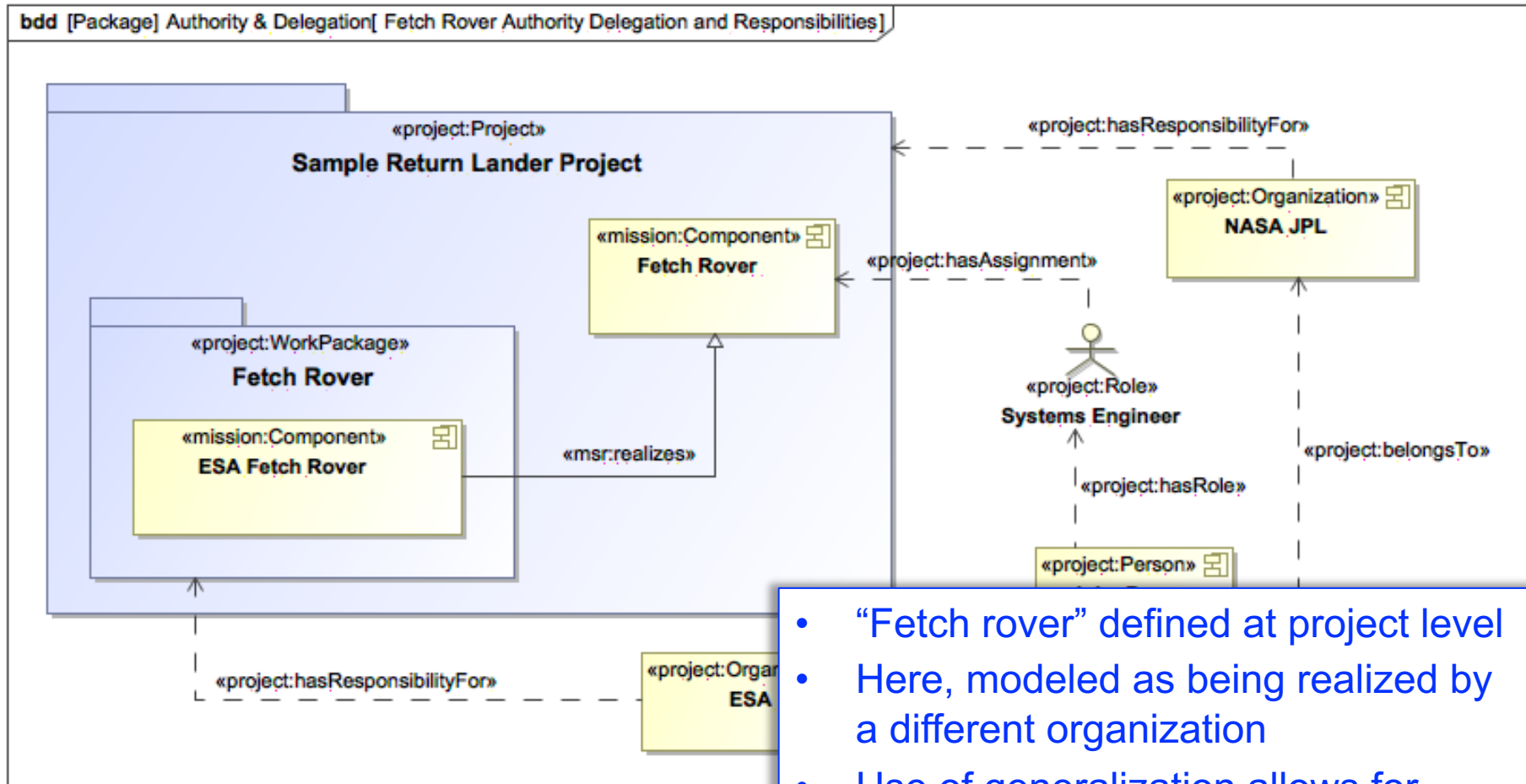
- **Operational scenarios:** modeled **78** operational scenarios to date, some of which are concrete variants of a more general scenario (9 scenarios that each have 2 variants)
- **Programmatic:**
 - Modeled all associated JPL personnel, and some personnel from other NASA centers, ESA
 - Partial set of roles and products
 - Organizations and their responsibilities
 - Draft mission objectives
- **Component decomposition:** decomposition of campaign into all major systems and subsystems, as well as traces to functions performed

Model Excerpts: Operational Scenarios

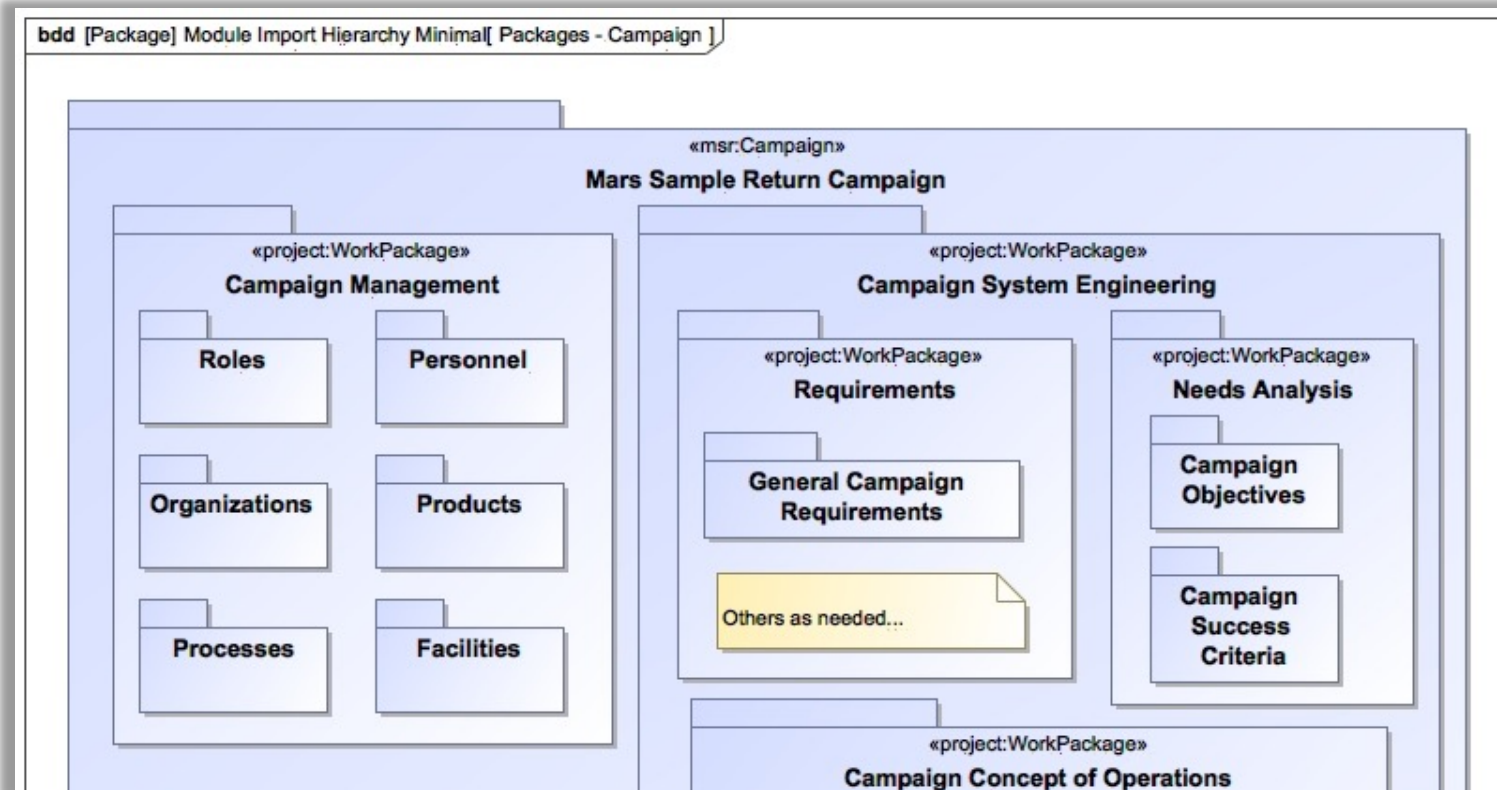
“BAT” Chart with Proposed Mission Phases (*SysML Activity Diagram*)



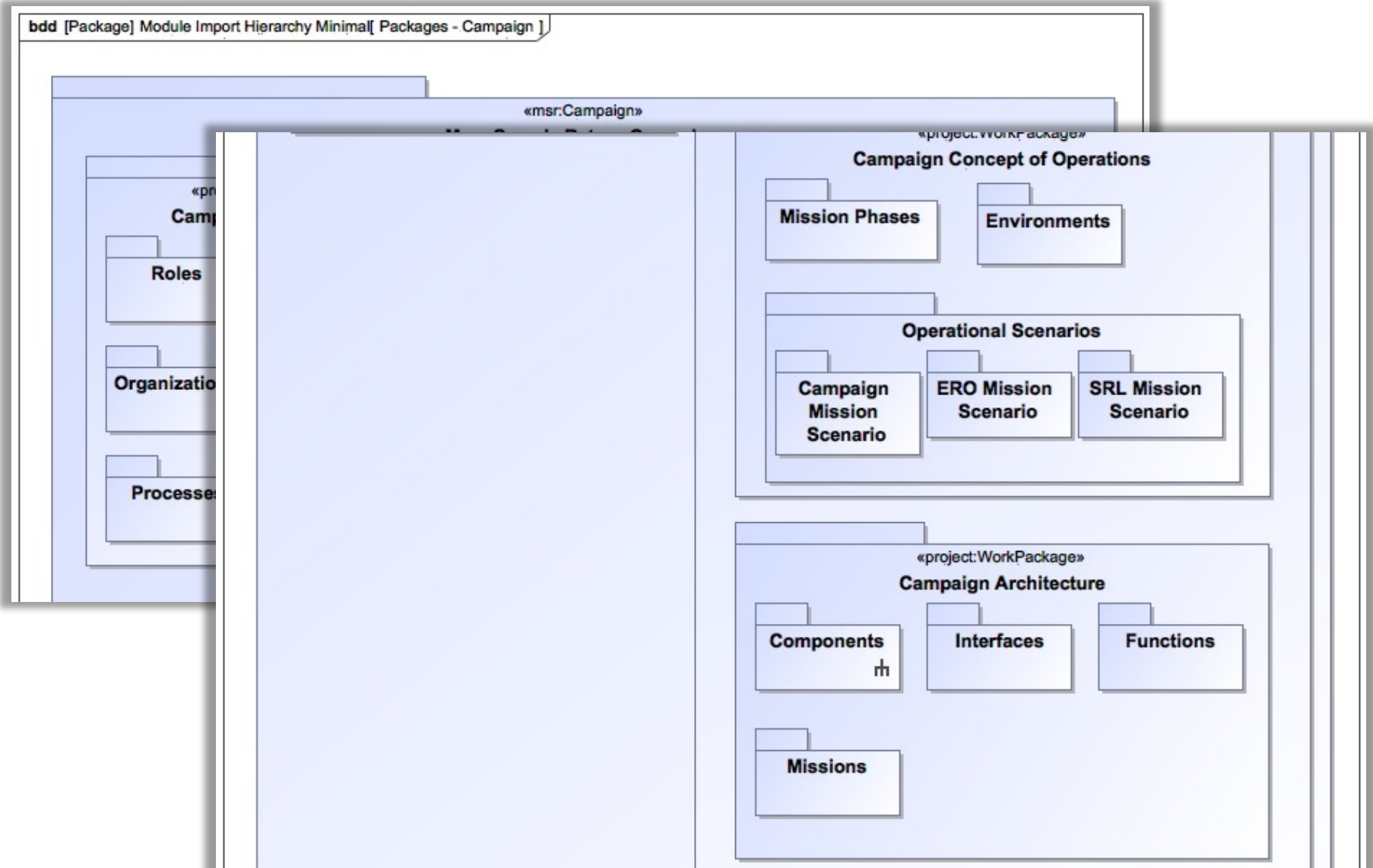
Model Excerpts: Responsibility Assignment



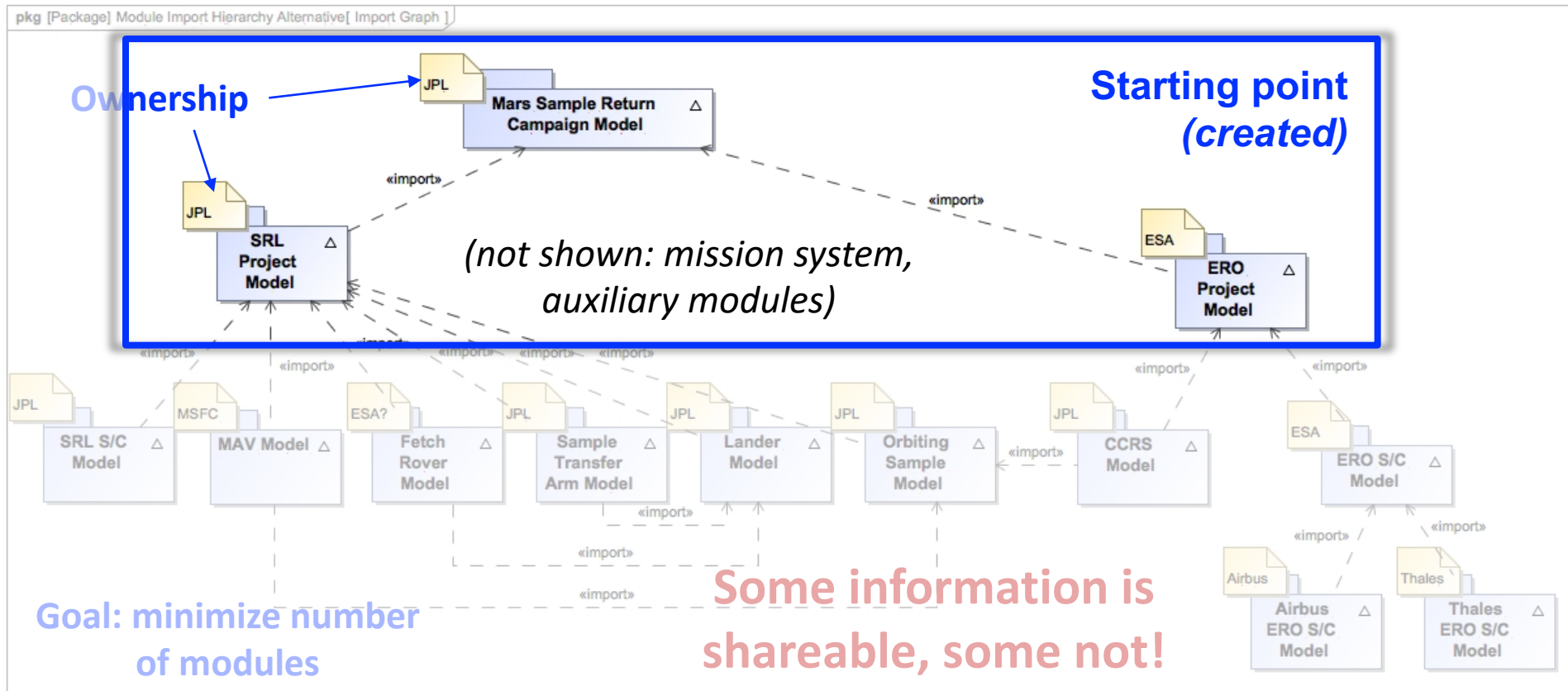
Model Excerpts: Package Organization



Model Excerpts: Package Organization



Data Segregation into Linked “Modules” as a Potential Solution



The importing module can *refer to*, but not *change* information in an imported module

Summary & Conclusions

- Presented SysML-based modeling approach for modeling a Concept of Operations
 - Introduced a number of modeling patterns
 - Demonstrated concepts through application to the CONOPS of a potential Mars Sample Return campaign
- Preliminary results demonstrate well how vocabulary extensions of UML / SysML greatly reduce ambiguity
 - “Embedded” domain-specific language: all constructs, and semantics of the UML / SysML language are preserved
- Identified challenges associated with having to segregate proprietary or controlled information when working on multi-agency, multi-center, multi-supplier efforts



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Backup Slides

Variation

